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The costs and a cost–benefit analysis of an *S. mansoni* control programme on an irrigated sugar estate in northern Tanzania

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On a sugar estate in northern Tanzania, an integrated control programme against Schistosoma mansoni *was carried out during the three years 1968–70 inclusive. The costs of that programme are defined, the costs of future snail control in the same area are estimated, and an attempt is made to evaluate the cost–benefit ratio of schistosomiasis control in the estate. The total expenditure on snail control was US$23 538, of which US$17 371 was spent on molluscicides and US$5 135 on labour. This represents an annual expenditure of approximately US$1.31 per estate resident. In the mass diagnosis and treatment campaign the main items in the total expenditure of US$37 043 were labour (US$13 724), drugs (US$4 218), hospital charges (US$8 262), and lost working days (US$8 760). It is estimated that the recurrent annual expenditure necessary to keep* S. mansoni *at a low level in the future would be US$7 714 on snail control and US$1 832 on detecting and treating new cases; however, the institution of a snail control programme would reduce the need for chemotherapy and would result in recurrent annual savings of US$7 448. In addition, it was estimated from a productivity study that savings of about US$14 000 per year could result if treatment of infected workers raised productivity by 5 %. The goodwill that resulted from the protection of wives and children against schistosomiasis would be a further benefit. When all factors are taken into account, snail control appears to be a feasible economic proposition.*

Although in most African countries there has been a significant decrease in the prevalence of many diseases and a general improvement in health standards, development programmes have often led to an increase in the prevalence of schistosomiasis. In many places water conservation and the provision of irrigation to arid and semi-arid areas are important aspects of development schemes. Such measures result in the creation of new habitats for the snail host of the schistosomes and increase the human–water contact, factors which give rise to a schistosomiasis problem where previously none existed, or at least to a significant increase in the problem.

The new molluscicides and improved drugs now available for use against the adult worms make it possible to contain the explosive increase of schistosomiasis, particularly where the production of valuable cash crops provides the basis for the necessary expenditure.

In northern Tanzania, the Tanganyika Planting Company created a sugar estate in an area with low rainfall by installing an irrigation network that supplies 80% of the water required by the crop. Predictably the bodies of water were invaded by snails, and one species, *Biomphalaria pfeifferi* (the host of *Schistosoma mansoni*), thrived in the irrigation canals and reservoirs, with the result that the disease became highly prevalent. In 1963, Foster (1967a) found that in field workers who had been on the estate at least 6 months the prevalence of infection was over 85% and the annual incidence of new infections was over 80%.

A programme was begun in 1968 to reduce the prevalence, the incidence, and the intensity of the disease in the short term by intensive control measures. The careful use of molluscicides controlled the snail host for a 3-year period (Fenwick, 1970) with the result that transmission was greatly reduced (Fenwick, 1972). A mass diagnosis and treatment campaign was then carried out to find and treat existing infections with the result that the overall prevalence of infection was reduced by about 50% and the

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intensity of infection, as measured by total egg output, by an estimated 85% (Fenwick & Jorgensen, 1972).

In this paper the total costs of the programme and the estimated recurrent expenditure for maintaining control in the future are presented. In addition, an attempt is made to estimate the benefits that should derive from the reduced need for chemotherapy and the increased productivity from the workers (Fenwick & Figenschou, 1972). The presumed benefits of a general improvement in the health of all residents and the goodwill involved are impossible to estimate.

THE COSTS OF THE 1968–70 CONTROL PROGRAMME

Snail control

Molluscicides. The routine snail control procedure developed in 1966–67 (Fenwick, 1970) was in operation for the whole of the 3-year period. Two molluscicides were used, *N*-tritylmorpholine (available as a 16.5% emulsifiable concentrate) and niclosamide (as a 70% water-dispersible powder of the ethanolamine salt).

N-tritylmorpholine was dripped into the headwaters of the two irrigation systems on the estate at the rate of 0.025 mg of active ingredient per litre for 5 days every 7 weeks during the dry season irrigation periods (40–52 weeks per year depending on rainfall). Over the 156 weeks of the programme, 18 treatments were applied to each system consuming in all 4 091 litres of *N*-tritylmorpholine concentrate, which at the market price of US $3.54 per litre cost US $14 482.

Niclosamide was used for treating the drainage ditches on the estate and for spot treatment of standing water when necessary. The drains were sprayed from knapsack sprayers every 10–12 weeks, after snails had been detected by routine sampling; altogether, 12 treatments were applied over the 3-year period and 480 kg of chemical was used. At US $6.02 per kg the cost of the chemical was US $2 889.

The total expenditure on molluscicide for the period 1968–70 was therefore US $17 371, an annual expenditure of US $5 790.

Labour costs. Application of the *N*-tritylmorpholine to the irrigation canals was a simple procedure involving (*a*) reading the water flow from a weir, (*b*) reading the chemical required from a table (1 litre per 77 litres/s flow), (*c*) pouring the chemical into a tank, and (*d*) filling the tank with water.

The task was given to the headman already employed to supervise the take-off of water from the river. On the 30 treatment days per year, the above job occupied him for 30 minutes per day and thus no extra labour cost was incurred. As the man lived at the site he was able to check the automatic introduction of molluscicide from time to time with little inconvenience.

The drainage ditch treatments were carried out by 4 labourers with knapsack sprayers, supervised and assisted by two men who were otherwise employed full-time on snail sampling. Over the 3-year period, 12 treatments at 2 days per treatment meant diverting men from other work for 96 man-days. At US $0.99 per day the total cost was US $95.

Snail sampling was carried out daily by two men who covered 16 sites per week. Their results served a dual purpose. Firstly their work checked the efficiency of the introduction of molluscicide into the irrigation canals and secondly it indicated when drainage ditches needed treatment. The latter was always carried out within one week of the discovery of *B. pfeifferi* snails.

At a salary of US $42 per month, the estimated cost of each of these two men to the company was US $70 per month (including housing and other benefits). The total cost of snail sampling for 36 months was thus US $5 040, and the total labour costs for snail control were therefore US $5 135 over the 3-year period, the average annual cost being US $1 712.

Transport costs. The two snail samplers used bicycles costing US $56 each, and during the 24 days of drainage ditch treatment over the whole period, a Land Rover was required at a cost of US $0.22 per km for an estimated 100 km per day, i.e., US $528. Thus the total transport costs over the 3 years were US $640, an annual cost of US $213, assuming a 3-year life for the bicycles.

Capital equipment. To dispense *N*-tritylmorpholine into the irrigation canals a building was erected over each of the two main canals to house a 400-litre concrete tank plus a simple water pump to fill it. The estimated cost of the buildings and equipment was US $280. For the drainage ditch treatment, 4 knapsack sprayers were required at a cost of US $112, bringing the total capital expenditure to US $392.

Mass diagnosis and treatment

A field laboratory was set up at the estate hospital where stool examinations were carried out as part of the programme to detect and treat infected persons and to reduce the prevalence and intensity of the disease and also to evaluate the effects of the control

programme. The number of stool examinations carried out was as follows:

(1) For the control programme	
(*a*) hospital inpatients—approximately 150 patients per month at 2 stools per patient for 30 months	9 000
(*b*) camp surveys	5 444
(*c*) screening of new employees—773 new employees at 4 stools per person	3 092
total no. of stools examined	17 536
(2) For evaluation purposes	
(*a*) 1969 prevalence survey—553 subjects at 4 stools per person	2 132
(*b*) 1970 prevalence survey—602 subjects at 4 stools per person	2 408
(*c*) follow-up of new workers at 6 and 12 months—270 men at 4 stools per man	1 080
(*d*) drug evaluation—650 subjects at 4 stools per person	2 600
total no. of stools examined	8 220

Labour costs

In order to examine these stools a staff of 6 was employed for the 3-year period: 1 field officer, salary US $2 801 per year, and 5 subordinate staff, salary US $336 per year each. The total cost of the staff, including benefits, amounted to US $13 724.

Laboratory equipment

The laboratory was provided with electricity and water. The main items of equipment were a centrifuge and three microscopes; other items used were microscope slides, cover slips, test tubes, stationery, and soap.

	US $
electricity and water at US $ 2.80 per month	101
centrifuge	140
3 microscopes	420
miscellaneous small items	98
total	759

Transport

For the daily collection of stool samples a Land Rover was provided for 12 months and it covered approximately 20 km per day. The total cost for 300 days at the rate of US $0.22 per km was US $1 320.

Treatment

Over the 3-year period 2 286 courses of drugs were administered, 1 455 courses of niridazole at US $1.54 and 831 courses of hycanthone at US $2.38, giving a total cost of US $4 218.

The treatment with niridazole necessitated an average stay in hospital of 3 days at US $1.54 per day: thus the cost of 1 455 courses was US $6 722. Hycanthone treatment was generally administered on an outpatient basis but 200 patients stayed in hospital for 5 days while the drug was being evaluated: the total cost of 1 000 hospital days at US $1.54 per day amounted to US $1 540.

Workers were unable to work during treatment at the rates of 7 days per course of niridazole and 2 days per hycanthone course. The cost of one lost day was estimated at US $0.98.

	US $
1 131 courses of 7 days at US $0.98 per day	7 758
511 courses of 2 days at US $0.98 per day	1 002
total	8 760

Total expenditure on the 3-year programme

The total expenditure on snail control, mass diagnosis, and treatment was thus as follows:

Snail control

	US $	
molluscicides	17 371	
labour	5 135	
transport	640	
capital equipment	392	
		23 538

Mass diagnosis, treatment, and evaluation

	US $	
labour	13 724	
laboratory equipment	759	
transport	1 320	
drugs	4 218	
hospital days	8 262	
lost working days	8 760	
		37 043
	total US $	60 581

All the above expenses were met by the Tanganyika Planting Co., except for the labour and transport costs involved in the mass diagnosis, treatment, and evaluation. These were met by the East African Tropical Pesticides Research Institute, which organized the programme and also paid the salary of the research officer who supervised it (the author).

Over the 3 years, US $23 538 was spent on snail control to protect almost 6 000 people from exposure to *S. mansoni* infection, i.e., US $3.92 per person or US $1.31 per person per year.

Estimated savings

During the four years 1957–60 inclusive, before molluscicide was used on the estate, the hospital records show that 8 057 treatments for schistosomiasis were administered—a mean of 2 014 per year. This figure cannot be safely applied to the years 1968–70 as the labour force was larger in the 1950s before the work had been mechanized. Foster (1967b) predicted that in the absence of control measures 1 350 treatments a year would be necessary and this figure is used as a conservative estimate for the 1968–70 period.

Thus it is estimated that the cost of 4 050 treatments should be deducted from the total cost of the control programme. The fact that this total is greater than the number of treatments actually administered in the programme, despite active searching for infected people, is a reflection of the difference between the effects of the irregular experimental snail control in the years 1962–67 and the full snail control in 1968–70.

If 3 000 of these 4 050 treatments had been with niridazole and 1 050 with the newer drug hycanthone, 2 000 workers receiving niridazole and 600 hycanthone, the costs would have been as follows:

	US $
3 000 courses of niridazole at US $1.54	4 620
1 050 courses of hycanthone at US $2.38	2 499
9 000 hospital days for niridazole treatment at US $1.54 per day	13 860
14 000 lost working days for niridazole treatment at US $0.98 per day	13 720
1 200 lost working days for hycanthone treatment at US $0.98 per day	1 176
total	35 875

Thus to arrive at the true cost of the programme it is estimated that US $35 875 should be deducted from the sum expended, US $60 581, making the true cost US $24 706.

ESTIMATED FUTURE EXPENDITURE TO MAINTAIN *S. MANSONI* CONTROL

It is expected that *S. mansoni* infection can be kept at a low level on the estate by continuing the snail control measures and at the same time screening new employees on arrival and treating the imported cases. The estimated number of drug treatments is 80 per year for prospective employees and 240 per year for residual and imported cases. In the costs of these measures tabulated below, the workers involved in snail control would also be responsible for the screening of new employees, hence no labour costs are shown under that heading. The recurrent costs of these measures would be:

	US $	
Snail control		
molluscicides	5 790	
labour	1 711	
transport	213	
		7 714
Screening of new employees		
laboratory expenses	140	
labour	0	
		140
Treatment of imported cases		
250 courses of hycanthone at US $2.38	595	
70 courses of niridazole at US $1.54	108	
210 hospital days for niridazole treatment at US $1.54	323	
330 lost working days for hycanthone at US $0.98	323	
350 lost working days for niridazole treatment at US $0.98	343	
		1 692
	total US $	9 546

BENEFITS THAT ARE EXPECTED TO ARISE FROM CONTINUED *S. MANSONI* CONTROL

It is very difficult to express in terms of money the benefits that arise from a reduction in *S. mansoni* prevalence and incidence. While a general improvement in health can be expected and is assumed, there is little objective evidence to prove to what extent this occurs. The tangible benefits of the programme on the sugar estate were a reduction of the required number of drug treatments and an improvement in the productivity of cane cutters estimated at 2.5–5.0% (Fenwick & Figenschou, 1972).

Savings from reduced chemotherapy

Assuming that in the absence of any control measures 1 350 treatments per year would be required and that two-thirds of those treated would be agricultural workers (as opposed to dependants), the savings would amount to:

	US $
350 courses of niridazole at US $1.54	539
1 000 courses of hycanthone at US $2.38	2 380
1 050 hospital days for niridazole at US $1.54	1 617
1 334 lost working days for hycanthone at US $0.98	1 307
1 638 lost working days for niridazole at US $0.98	1 605
total	7 448

SAVINGS EXPECTED TO RESULT FROM INCREASED PRODUCTIVITY

It has been shown (Fenwick & Figenschou, 1972) that over a 2-year period uninfected cane cutters earned significantly more bonus (about 11%) for their work than infected cane cutters. In terms of productivity it is estimated that this means a difference of 2.5–5.0%.

At the end of 1970, the 1 700 field labourers could be classified as follows with respect to infection with *S. mansoni*:

5.2% infected, not previously examined, and not treated	87 men
12.5% infected, but with a light infection not detected on a previous single stool examination	213 men
13.6% infected and treated but not cured	232 men
27.6% uninfected as a result of treatment	469 men
41.1% uninfected	699 men
total	1 700 men

Since future snail control should afford complete protection against schistosomiasis, the output of the 1 700 men with the distribution shown above should be compared with that of 1 700 men with an overall infection rate of 85% as found by Foster (1967). With an 85% infection rate there would have been only 255 uninfected men, 444 fewer than the 1970 figures show. If a 5% difference in productivity between infected and uninfected men is assumed, the additional 444 uninfected men in 1970 would do the work of 466 infected men, thus saving the company employing an additional 22 men. Fenwick & Figenschou (1972) have shown that infected men improved their output after treatment but did not equal the productivity of uninfected workers (at least within 1 year). If it is assumed that they achieved a 2½% improvement in output the 701 treated men could be expected to do the work of 717 infected men, thus saving the employment of a further 16 men. The cost to the company of employing 38 extra men at US$35 per month would be US$15 960. This takes no account of increased productivity by non-field workers.

Thus the total annual benefits from future *S. mansoni* control will be:

		US $
treatment savings		7 448
productivity savings		15 960
	total savings	23 408
less the cost of control		9 546
	total benefits	13 862

DISCUSSION

The costs incurred in carrying out a 3-year snail control programme on an irrigated sugar plantation in Tanzania have been clearly set out and the cost of future snail control on the same plantation can be accurately estimated. The estimated benefits likely to arise from these measures, however, will depend on the correctness of the assumptions upon which the estimates are based.

However, it does appear that on this estate the cost of future snail control measures will be covered by savings derived from a reduction in the number of drug treatments required. Any savings derived from increases in productivity would be an extra advantage, as would be the goodwill involved in keeping the estate residents free from infection with presumably healthier wives and children. The results of this study thus show that snail control on this sugar estate was a feasible and worthwhile undertaking.

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RÉSUMÉ

COÛT ET ANALYSE DU RAPPORT COÛT-BÉNÉFICE D'UN PROGRAMME DE LUTTE CONTRE *SCHISTOSOMA MANSONI* DANS UNE PLANTATION DE CANNES À SUCRE POURVUE D'UN SYSTÈME D'IRRIGATION, DANS LE NORD DE LA TANZANIE

De 1968 à 1970, on a appliqué un programme de lutte contre la schistosomiase à *Schistosoma mansoni* dans une plantation de cannes à sucre de Tanzanie. Il a comporté l'emploi intensif de molluscicides pour détruire les populations de *Biomphalaria pfeifferi* et, concomitamment, une campagne de diagnostic et de traitement de masse destinée à réduire la prévalence de la maladie.

Le coût total de la lutte anti-mollusques a été de

$ 23 538, représentant une dépense annuelle approximative de $ 1,31 par personne résidant sur la plantation. La plus grande partie de ce montant a été consacrée à l'achat des molluscicides ($ 17 371) et au paiement de la main-d'œuvre ($ 5135).

La campagne de diagnostic et de traitement a nécessité l'examen de plus de 17 000 échantillons de selles; plus de 8000 examens ont été effectués pour évaluer les résultats du programme. On a administré 1455 traitements par le niridazole et 831 traitements par l'hycanthone. Le coût total de l'opération s'est élevé à $ 37 043, soit $ 13 724 pour la main-d'œuvre, $ 8760 pour la perte de journées de travail, $ 8262 pour les frais d'hospitalisation et $ 4218 pour l'achat des médicaments.

L'ensemble du programme a donc exigé une dépense de $ 60 581.

On estime que pour maintenir la prévalence de la schistosomiase à un faible niveau, il faudrait consacrer annuellement $ 7714 à la lutte contre *B. pfeifferi* et $ 1832 au dépistage et au traitement des nouveaux cas. Cependant, en atténuant la transmission de *S. mansoni*, l'emploi des molluscicides a pour effet de diminuer le nombre des cas et des traitements et assurerait une économie annuelle d'environ $ 7500. On admet en outre que le traitement des travailleurs atteints de schistosomiase accroît leur productivité de 5%, d'où un gain annuel de $ 16 000. Enfin, la protection contre la schistosomiase octroyée à la famille des travailleurs est un avantage indirect appréciable.

Pour ces diverses raisons, la lutte anti-mollusques apparaît comme un investissement utile à la fois pour la compagnie exploitante et pour ses employés.

REFERENCES

Fenwick, A. (1970) *Bull. Wld Hlth Org.*, **42**, 529
Fenwick, A. (1972) *Bull. Wld Hlth, Org.*, **47**, 325
Fenwick, A. & Figenschou, B. H. (1972) *Bull. Wld Hlth Org.*, **47**, 567
Fenwick, A. & Jorgensen, T. A. (1972) *Bull. Wld Hlth Org.*, **47**, 579
Foster, R. (1967a) *J. trop. Med. Hyg.*, **70**, 159
Foster, R. (1967b) *J. trop. Med. Hyg.*, **70**, 185